AUTOMATIC LEVEL-CONTROL FLOATING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an automatic level-control floating apparatus, which supports a superstructure and constantly controls the level (vertical position) of the supported superstructure. The superstructure may be a pontoon bridge or a floor that floats on the sea.

In order to eliminate the need to adjust the level of a known pontoon bridge, which may vary in level, a long movable ramp is provided between the bridge and the land. Because the ramp slopes as the pontoon bridge varies in level, it cannot be used where it needs to be horizontal.

The pontoon of another known pontoon bridge is fitted with ballast pumps for pumping water into and from the pontoon to adjust the level of the bridge. For example, reference may be made to Japanese Unexamined Patent Publication No. H11-172620 (paragraph 0009, Fig. 1). Because the ballast pumps need to keep operating, the pontoon bridge requires high running costs for the operation, maintenance, etc. of the pumps.

In general, the foundations of the piers of bridges constructed on the sea etc. need to be laid on firm ground. If the foundations are laid on very soft ground, or if they are very deep in water, the construction costs of the bridges are very high.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an automatic level-control floating apparatus including a displacer-type float that makes it possible to reduce the equipment and running costs.

The present invention is based on the fact that the level of the superstructure resting on the floating bodies in the floating tanks of the displacer-type float can be kept constant regardless of the variation in tide level or the like. The invention is also based on the fact the displacer-type float is moved by its buoyancy and needs no motive power.

An automatic level-control floating apparatus according to a first aspect of the present invention comprises a fixed casing, a piston body, a floating tank, a floating body and a communicating line. The fixed casing rests on the water bottom or is supported by a support set on the water bottom. The top of the fixed casing is open to the atmosphere. The fixed casing is filled with liquid. The piston body is floating on the liquid in the fixed casing in such a manner that this body can move vertically. The piston body is integral with the floating tank, which is positioned outside it. The floating tank is floating on the water and filled with liquid. The top of the floating tank is open to the atmosphere. The floating body is floating on the liquid in the floating tank in such a manner that this body can move vertically. The floating body supports the bottom of a superstructure above

the water. The interior of the floating tank and the interior of the fixed casing are connected by the communicating line, through which the liquid can flow between the tank and the casing so that the level of the floating body can be controlled automatically.

When the water level rises, the floating tank moves upward together with the piston body. This makes the liquid level in the fixed casing lower than that in the floating tank, so that a portion of the liquid in the tank flows into the casing. Consequently, the liquid level in the floating tank lowers relatively.

In other words, as the piston body moves upward in the fixed casing, a portion of the liquid under the floating body in the floating tank flows into the casing, so that the floating body moves downward in the tank. The upward displacement of the floating tank is roughly equal to the downward displacement of the floating body in this tank. As a result, the level of the floating body is kept roughly constant. Likewise, when the water level drops, the level of the floating body is kept roughly constant.

Thus, when the displacer-type float including the piston body and the floating tank moves vertically, a portion of the liquid flows through the communicating line between the tank and the fixed casing, so that the liquid levels in the tank and the casing become the same.

The fixed casing needs to rest on the water bottom directly or with a support interposed between them. Only part of the load of the floating apparatus acts on the support, because buoyancy acts on the floating tank, which is integral with the piston body. Accordingly, the load acting on the support is roughly equal to only the load of the fixed casing, so that the support can be simple in structure.

The simple support can be low in strength and light in weight as compared with a structure set up on the water bottom. Even if the water bottom is soft, the simple support can be set up without being reinforced by means of large-scale ground improvement or the like.

It is preferable that the communicating line be a flexible and elastic tube, which can follow the floating tank without breaking even if this tank is displaced greatly relative to the fixed casing.

A plurality of automatic level-control floating apparatuses according to the first aspect may be provided and spaced from each other. A superstructure is positioned over the floating apparatuses. A connector is interposed between the superstructure and the floating body of one of the floating apparatuses. The connector allows the superstructure and the floating body to be displaced relative to each other.

The cross-sectional areas of the piston body and the interior of the floating tank or the ratio between them depends on the composition of the vertical displacement of the floating body due to its buoyancy and the displacement of the liquid level in the floating tank. These areas or the ratio between them may be determined suitably so that the level of the floating body can be kept constant even when this body is displaced vertically by a change of tide level. It is preferable that the cross-sectional area ratio be about 1.

The absolute change of the liquid level (the absolute movement of the floating body) in the floating tank depends on the ratio between the cross-sectional areas of the piston body and the interior of the floating tank. If this ratio is 1, the vertical displacement of the floating body is 0. Accordingly, even when the displacer-type float is moved vertically by a change of tide level, the level of the floating body is kept constant.

The superstructure may be a pontoon bridge. This makes it easy to control the level of the pontoon bridge.

An automatic level-control floating apparatus according to a second aspect of the present invention comprises a support, an annular fixed casing, an annular piston body, a floating tank, a floating body and a communicating line. The support is set on the water bottom. The annular fixed casing is supported by the support. The top of the fixed casing is open to the atmosphere. The fixed casing is filled with liquid. The annular piston body is floating on the liquid in the fixed casing in such a manner that this body can move vertically. The floating tank is integral with and positioned within the piston body. The floating tank is floating on the water. The top of the floating tank is open to the atmosphere. The floating tank is filled with liquid. The floating body is floating on the liquid in the floating tank in such a manner that this body can move vertically. The floating body supports the bottom of a superstructure above the water. The interior of the floating tank and the interior of the fixed casing are connected by the communicating tube, through which the liquid can flow between the tank and the casing so that the level of the floating body can be controlled automatically. The superstructure may be a floor floating on the sea or the water.

The support may comprise a tension anchor, which includes an anchor fixed to the water bottom and a chain or a wire rope connecting the anchor and the fixed casing.

The floating apparatus according to the present invention does not need a pump or other machinery or equipment for level control, and accordingly does not require electric or motive power. This makes it possible to greatly cut down the running costs for the operation, maintenance, etc. of the apparatus.

In particular, because the displacer-type float (the piston body and floating tank) of the floating apparatus is not fixed to the ground, it can be less affected by earthquakes than general bridges, for which foundations need to be built. If the fixed casing is built on the ground in consideration of the ground-water level etc., the casing needs no great bearing power. This is economical if the ground is very soft or if the water is very deep.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a vertical section of an automatic level-control floating apparatus according to a first embodiment of the present invention at low tide.

Fig. 2 is a vertical section of the floating apparatus according to the first embodiment high tide.

Fig. 3 is a vertical section of an automatic level-control floating apparatus

according to a second embodiment of the present invention at low tide.

Fig. 4 is a top plan of an end portion of the floating apparatus according to the second embodiment.

Figs. 5a and 5b are vertical sections of an automatic level-control floating apparatus according to a third embodiment of the present invention at low tide and high tide, respectively.

Fig. 6 is a vertical section showing a floating floor supported on automatic level-control floating apparatuses according to the third embodiment.

Fig. 7a is a vertical section of part of an automatic level-control floating apparatus according to the third embodiment. Fig. 7b is a vertical section of an upper portion of the bearing pile shown in Fig. 7a.

Fig. 8 is a view showing the relationship between the bearing pile and dampers shown in Fig. 7a.

Fig. 9 is a view showing another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figs. 1 and 2 show an automatic level-control floating apparatus according to a first embodiment of the present invention at low tide and high tide, respectively.

With reference to Figs. 1 and 2, protrusions S1, one of which is shown, are formed on the sea bottom S. A cylindrical supporting tank (fixed casing) 3 made of steel rests on each protrusion S1 and includes a bottom plate 3a and a peripheral wall 3b. The top of the supporting tank 3 is open to the atmosphere. The bottom plate 3a is fixed on the top of the protrusion S1. The peripheral wall 3b stands vertically on the periphery of the bottom plate 3a. A top portion of the peripheral wall 3b protrudes above seal level. The supporting tank 3 is filled with liquid 8.

A displacer type float F consists of a cylindrical piston body 1 and two cylindrical floating tanks 2. The outer diameter of the piston body 1 is slightly smaller than the inner diameter of the peripheral wall 3b of the supporting tank 3. The piston body 1 is floating on the liquid 8 in the floating tank 3 and can vertically reciprocate in this tank 3. A top portion of the piston body 1 protrudes into the atmosphere above sea level. The bottom of the piston body 1 is fitted with an optional piston part 1a, which can vertically slide in the tank wall 3b. The piston body 1 has two connecting arms 1b formed on diametrically opposite sides of its top. The connecting arms 1b extend outward radially of the piston body 1 beyond the tank wall 3b and protrusion S1. The outer end of each supporting arm 1b is connected integrally with one of the floating tanks 2. The tops of the floating tanks 2 are open to the atmosphere. The floating tanks 2 are filled with liquid, as is the case with the supporting tank 3. A lower portion of each floating tank 2 that is larger than its half is immersed in the sea. The floating tanks 2 are floating on the sea around the protrusion S1 on the sea bottom S.

The connecting arms 1b and floating tanks 2 are bilaterally symmetrical around and integral with the piston body 1. A cylindrical floating body 4 is floating on the liquid in each floating tank 2. The outer diameter of the floating bodies 4 are

slightly smaller than the inner diameter of the floating tanks 2.

The interior of each floating tank 2 is connected with the interior of the supporting tank 3 by a polyethylene hose or another flexible and elastic communicating tube (line) 5, through which the liquid in them can freely flow between them.

A pontoon bridge (superstructure) 6 rests on the symmetrical floating bodies 4 in bilateral symmetry and in balance through shoes or other connectors 7, which allow the bridge 6 and each floating body 4 to be displaced relative to each other.

As the height of tide (the tide level) changes, the piston body 1 and floating tanks 2 vertically move, changing the liquid level in the supporting tank 3, where the piston body is floating. As the liquid level changes, the liquid moves through the communicating tubes 5, changing the liquid levels in the floating tanks 2. As a result, the liquid levels in the three tanks 2 and 3 are kept adjusted to the same height. How much the liquid levels change depends on the ratio between the cross-sectional areas of the piston body 1 and the interior of each floating tank 2. Likewise, it depends on this area ratio how much the floating bodies 4 in the floating tanks 2 vertically move.

As the sea level changes, the displacer-type float F, which is floating on the sea, is vertically moved by its buoyancy without requiring motive power. The float F could be floated on a lake or in a reservoir or the like with a similar effect.

Thus, even if the height of tide rises, the floating tanks 2 move upward together with the piston body 1, which is fixed to them. The upward movement of the piston body 1 in the supporting tank 3 causes part of the liquid under the floating bodies 4 in the floating tanks 2 to flow into the tank 3, so that the bodies 4 move downward in the tanks 2.

The upward movement of the floating tanks 2 due to the rising tide and the downward movement of the floating bodies 4 in them are roughly equal to each other and cancel each other out. Accordingly, the levels of the floating bodies 4 are kept constant. Likewise, when the height of tide falls, the levels of the floating bodies 4 are kept constant.

Thus, even if the sea level either rises or falls, the levels of the floating bodies 4 are kept constant, so that the level of the pontoon bridge 6 on the bodies 4 is constant. Even if the bridge 6 crosses the sea between two lands, and even when the sea level changes, the level of the bridge 6 is kept constant. Accordingly, if the bridge 6 is initially horizontal, it is kept horizontal.

In this embodiment, the supporting tank 3 rests on the sea bottom. Alternatively, a supporting tank may rest on a bearing pile set on the sea bottom, as shown in Figs. 3 and 4, which show an automatic level-control floating apparatus according to a second embodiment of the present invention.

With reference to Figs. 3 and 4, a quay wall 11 is formed with a recess 12, where a columnar bearing pile (a support) 13 is set with its axis roughly vertical on the bottom S of the sea 9. A cylindrical supporting tank 3 is fixed on the top of the pile 13 coaxially with it. The bottom of a piston body 1 is fitted with an optional circular piston part 1a, which can vertically slide in the supporting tank 3. Two floating tanks 2 are fixed integrally with the piston body 1. One end of

a pontoon bridge 6 and the quay wall 11 are connected by a connecting plate 14.

It is preferable that a partition (not shown) be set on the open side of the recess 12 to prevent the entrance of the waves from the sea 9 into the recess 12 so that the floating tanks 2 cannot shake.

The other parts of the floating apparatus are common to the first and second embodiments and assigned the same reference numerals for the two embodiments, without being described below.

The floating tanks 2 are square in horizontal section and connected integrally with diametrically opposite sides of the piston body 1. Alternatively, the floating tanks 2 might be semicircular in horizontal section and connected integrally with the side of the piston body 1 that is away from the quay wall 11.

This embodiment, where the supporting tank 3 rests on the bearing pile 13, is suitable if the sea bottom S is soft.

In each of the first and second embodiments, the floating tanks 2 are positioned in bilateral symmetry around the piston body 1 and connected integrally with diametrically opposite sides of this body 1. Alternatively, a piston body may be provided in symmetry around a floating tank, as shown in Figs. 5a and 5b, which show an automatic level-control floating apparatus according to a third embodiment of the present invention at low tide and high tide, respectively.

With reference to Figs. 5a and 5b, two or more bearing piles 13A, which may be steel pipes, are set at regular intervals in a circle on the sea bottom. An annular supporting tank 3A is fixed on the bearing piles 13A. A displacer-type float F' consists of an annular piston body 1A and a cylindrical floating tank 2A. The piston body 1A can move vertically in the supporting tank 3A. The floating tank 2A is positioned within the piston body 1A coaxially with it and connected to it. A floating body 4A is floating on the liquid in the floating tank 2A and can vertically reciprocate. The tanks 2A and 3A are connected together by a suitable number of flexible connecting tubes 5A.

Fig. 6 shows a floating floor 21 supported on automatic level-control floating apparatuses according to the third embodiment. The floating floor 21 is rectangular in plan view and supported near its four corners on floating apparatuses as shown in Figs. 5a and 5b.

With reference to Fig. 6, the floating floor 21 lies on a platform 22, which rests on the floating bodies 4A in floating tanks 2A. The platform 22 also rests on struts 23 standing on other floating bodies 24A and 24B. There is a sufficient clearance between the platform 22 and each supporting tank 3A so that the vibration of the tank 3A is not transmitted to the platform 22 when an earthquake or the like occurs.

As shown in Figs. 7a and 7b, the inner periphery of each floating tank 2A is fitted with fenders 31 as buffers between it and the periphery of the associated floating body 4A. Likewise, the outer peripheral wall of each supporting tank 3A is fitted with fenders 32 inside it as buffers between this tank 3A and the associated piston body 1A. The fenders 32 prevent the deviation of the displacer-type floats F.